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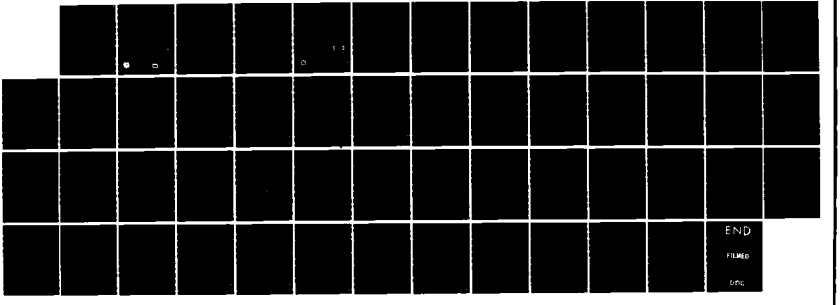

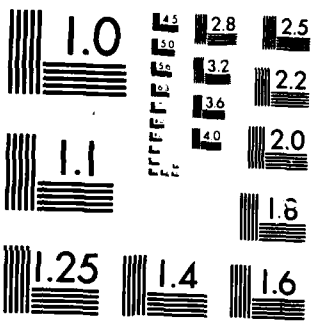

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DEPARTMENT OF OCEANOGRAPHY
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

TECHNICAL REPORT 83-7

GEOLOGICAL AND GEOCHEMICAL ANALYSIS OF SEABED STABILITY AT THE NORFOLK OCEAN DISPOSAL SITE
PART II: GEOCHEMICAL ANALYSIS

By

George T. F. Wong, Co-Principal Investigator

Progress Report
For the period ending September 15, 1983

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
803 Front Street
Norfolk, Virginia 23510

Under
Contract DACW65-81-C-0051
Work Orders: 0007 and 0008

US Army Corps
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September 1983

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Seabed at the site is highly dynamic; sedimentation rates at different locations of the disposal site were not uniform; recent material with an age less than ten years was deposited at site; source material for the sediments had varied with time; depth profiles suggest either spatial inhomogeneity of sediment composition or movement of sediments by storms.

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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508

September 1983

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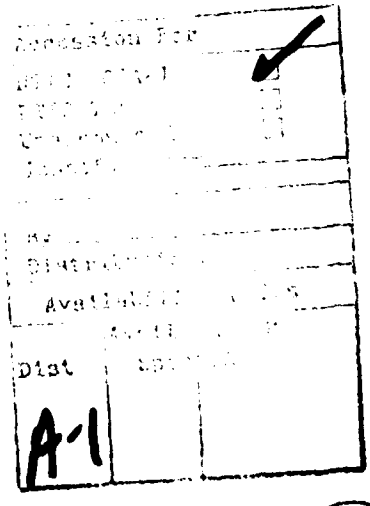
This project required extensive field and laboratory work which involved a number of graduate students. The field sampling program and geological analyses were conducted by M. Brynes, K. Gingerich, D. Knowles and R. Sawyer under the supervision of G. Oertel. T. Oatts and J. Todd carried out the geochemical analyses. K. Mukherjee did the typing and M. Seguinot prepared all the figures, for this report.



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GEOLOGICAL AND GEOCHEMICAL ANALYSIS OF SEABED STABILITY AT THE NORFOLK OCEAN DISPOSAL SITE PART II: GEOCHEMICAL ANALYSIS

By

George T. F. Wong*

A. INTRODUCTION

One of the many pieces of essential information for evaluating the acceptability of an ocean disposal site is the fate of materials dumped in that location. In Part I of this report, the stability of the seabed at the Norfolk Ocean Disposal Site (NODS) (figure 1) has been evaluated by using geological data including temporal changes in bathymetry, grain size analyses of the sediments and X-ray radiographs of intact cores. In this report, the seabed stability and recent sedimentary processes at this disposal site will be further examined by studying several bulk properties and the distribution of two naturally occurring radionuclides, Th-228 and Th-232, in cores.

B. SAMPLING AND ANALYTICAL PROCEDURES

1. Box Core Retrieval and Processing

Twenty box cores were collected from a one square nautical mile portion of the seabed near the center of NODS (figure 2) on June 26, 1982. These cores were returned to the laboratory and kept moist and cool. Seven of

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these twenty cores were selected for the determination of bulk properties and for radiochemical analyses. The selection was made based on a compromise of two criteria: (1) the cores should cover as much of the sampling area and as many contrasting sedimentary environments in the sampling area as possible and (2) cores which were dominated by coarse-grained and carbonaceous material upon visual examination of the surface of the cores (e.g. those covered with shell material and lack evidence of biogenic activities) were to be avoided since the unsupported thorium-228 is expected to be associated preferentially with fine-grained material. The locations of the cores are shown in figure 3 and listed in table 1.

Twenty box-cores were also collected from the same area on September 9, 1982. Again, seven cores were selected for further examination. In this case, a third selection criterion was imposed: cores collected from the same locations as those obtained in June were preferred. The locations of the cores are shown in figure 4 and compiled in table 2.

Upon return to the laboratory, the cores were processed within 48 hours. Cores were carefully extruded from their stainless steel core liners (10.5 cm x 17.5 cm x 35 cm) into plexiglass trays (2.5 cm x 17.5 cm x 36 cm). Each core was divided into slabs with a surface area of 8 cm x 17.5 cm between the surface and the limit of penetration (figure 5) for the determination of bulk properties and for radiochemical analyses. The core was sectioned in 1-cm intervals between the surface and 3 cm, in 2-cm intervals between 3 to 9 cm, and in 5-cm intervals between 9 cm and the bottom of the core. Only the central part of each slab was used for the analyses since the edges of the core which were in contact with the core liner might have been contaminated and/or disturbed during the coring process.

(Oertel, 1983), the contribution from the latter source is expected to be small.

A total of 98 samples of sediments from the 14 cores were analyzed for water content and porosity while 118 samples were analyzed for LOI.

3. Radiochemical Analysis

The concentrations of Th-232 and Th-228 in the dried sediments were determined by a method modified from those of Ku (1966), Koide et al. (1973), Aller et al. (1980) and Anderson (1981). Briefly, about 5 gm of ashed sediments were leached with hydrochloric acid in the presence of a known amount of added Th-229, which acted as the yield tracer. The thorium isotopes and a number of other radionuclides were removed from the leachate by co-precipitation with iron and aluminum hydroxides. The precipitates were redissolved. Thorium was separated from a number of other radioactive nuclides by passing the solution through an anion exchange column in the chloride form and then eluting the column by a serial gradient elution with hydrochloric acids at various concentrations. Thorium was separated from aluminum by co-precipitating thorium with iron hydroxide in sodium hydroxide, re-dissolving the iron hydroxide and then passing the solution through a cation exchange column and then eluting the column with hydrochloric acid and then oxalic acid. The oxalic acid solution which contained the thorium was converted to a nitric acid medium and thorium was separated from iron by passing the solution through an anion exchange column in the nitrate form and then eluting the column with hydrochloric and then nitric acid. The thorium, which was in the nitric acid, was electroplated onto a silver disk after the solution was converted to an ammoniacal medium, and then measured

by alpha spectrometry.

Fifty-six samples from seven cores obtained in June and six cores obtained in September were analyzed for Th-228 and Th-232.

C. EVALUATION AND DISCUSSION OF SEABED STABILITY AND SEDIMENTARY PROCESSES

1. Bulk Property Analysis

The data obtained from the cores are shown in figures 10-17 and are listed in appendix 1. In the cores obtained in June, the water content and porosity of the cores at stations 7, 13, 14, 15, 16 and 20 were quite uniform with depth. The porosity of 40% is indicative of highly sandy sediments and all the cores contained more than 94% of sand (Oertel, 1983). The core at station 3 also had quite uniform but somewhat lower porosity of 35%. The porosity in the top cm at this station was only 28%. The weight loss on ignition (LOI) of 0.5 to 0.7% through the entire core at this station was also relatively low. At all the other stations, values of LOI between 0.6% to greater than 1% were observed. Since organic materials are known to associate preferentially with fine-grained material, and fine-grained material should accumulate preferentially in low energy environment with greater bed stability, the data suggest that station 3 represents a less stable area. The same conclusion was arrived at based on geological analyses (table 1).

Among the other stations, stations 15 and 20 had the highest LOI. If the same reasoning is applied, this implies that the relative bed-stability at these two stations may be the highest. It is interesting to note that station 15 was situated in a depression in the channel where material was likely to accumulate. Furthermore, although stations 7, 13, 14, 15 and 20

were all classified as 'very stable' according to geological analyses (table 1), only stations 15 and 20 were considered most stable in all three evaluation criterion used (Oertel, 1982).

With the exception of station 3, a maximum in LOI was invariably observed in the top two cm. A broad minimum was observed between 2 and 7 cm. At 7 to 9 cm, LOI increased again, below 9 cm, LOI was quite constant in most cases with values between 1 to 1.5%. This distribution suggests that the source materials for the sediments may have varied with time. If material with a uniform initial organic content had been deposited continuously at a constant rate, LOI should decrease monotonically with depth as an increasing fraction of the organic matter was oxidized with time.

In the cores obtained in September, a rather uniform porosity of about 40% was again observed at stations 9, 13, 14, 15 and 20. A slight decrease in porosity in surface sediments was observed at stations 13 and 14. The porosity at station 6 was uniform at 35%. At station 3, the porosity was lower still and the porosity decreased towards the surface.

At station 3, LOI was again lowest. In fact, LOI never reached 0.5% in the entire core. This is again an indication that the seabed stability at station 3 was probably the lowest as concluded from geological analysis, (Oertel, 1983). A mid-depth minimum in LOI was again observed at stations 6, 9, 13, 15 and 20. At station 14, a surface minimum in LOI was observed. Again, these depth profiles of LOI suggest that the sedimentary processes were complex and the sedimentary materials might well have been variable both in terms of source and composition with time.

Cores were obtained from approximately the same locations at five stations (stations 3, 13, 14, 15 and 20) in June and in September. Sub-

stantial changes in both porosity and LOI in the entire length of the core were observed at station 3. Changes in LOI in the entire core were observed at stations 15 and 20. At stations 13 and 14, changes in LOI in at least the top 9 cm were evident. These temporal changes may be explained either by extreme spatial inhomogeneity of the sediments at the sampling area or by disturbances of the sediments in the intervening months. Neither possibilities can be discarded at the present time. Although every effort was made to obtain cores from the same location in June and September, it is unlikely that the same exact location was sampled during both cruises because of the inherent navigational uncertainties. On the otherhand, three major storms did pass over the sampling area between June and September. It should be emphasized that the disturbances of the sediments that are necessary to cause the changes in the profiles involved sediments in the upper 20 cm or less. Any changes in bathymetry would be well within the uncertainties of bathymetric surveys and may not be detected by geological analysis.

2. Thorium Isotopes

a. The Aquatic Geochemistry of Th-228 and Its Use as a Tracer for Sedimentary Processes.

Th-228 is a naturally occurring radionuclide with a half life of 1.9 years. It is a member of the Th-232 series (figure 6). Since Th-232 has a half life of 1.39×10^{10} years which is much longer than those of its daughters, in a closed system, given sufficient time, all the radioactive daughters should reach a secular equilibrium with Th-232 so that the activity ratio of any particular daughter to Th-232 will be unity. In the natural environment, radioactive dis-equilibria between Th-232 and its daughters are often observed as a result of the differences in their

geochemical properties. Thorium is a highly particle reactive element existing as the insoluble oxides and/or hydroxides (Brewer, 1975) which can be readily adsorbed onto particulate surfaces. On the other hand, Ra-228 (with a half life of 5.75 years) the intermediate between Th-232 and Th-228, is quite soluble and forms a readily soluble cation. Thus, the concentrations of Th-232 is negligibly small in comparison to Ra-228 in natural waters (Miyake et al., 1973; Knauss et al., 1978; Moore, 1981a). (The amount of Ra-228 in excess of its parent Th-232 is called unsupported Ra-228). Unsupported Ra-228 may be supplied to the estuarine and coastal marine waters through three different routes (figure 7). It is carried to these environments in river runoff in the dissolved form. Ra-228 is also adsorbed onto riverine sediments in fresh water and then desorbed under more saline conditions (Li et al., 1977; Li & Chan, 1979; Elsinger and Moore, 1980, Moore, 1981b). Desorption is apparently completed at relatively low salinities ($\lesssim 20^{\circ}/00$). Ra-228, which is formed by the decay of Th-232 in the sediment, also diffused into the water column. The unsupported dissolved Ra-228 in the water column may then be transported and homogenized by physical mixing. It will also decay to form Th-228 in the process. Once Th-228 is formed, it is rapidly scavenged and then removed to the sediment. The residence time of dissolved thorium in coastal waters has been estimated to be days (Santschi et al., 1979). This fraction of Th-228 in the sediment which is called unsupported Th-228 can then be used for tracing sedimentation processes. There are two other sources of authigenic Th-228 in the sediments that are not related to the sedimentary processes: (1) as a decay product of Th-232 in the sediment and (2) from unsupported Ra-228 in the sediment which is deposited from seawater. These two fractions constitute the supported

the supported Th-228.

If particle by particle and continuous sedimentation at a constant rate occurs at a given location, Koide et al. (1973) suggested that the contribution of supported Th-228 may be approximated by the lowest measured values of Th-228 to Th-232 activity ratio found at depth in a core so that

$$\left(\frac{A_c}{A_a}\right)_u = \left[\left(\frac{A_c}{A_a}\right)_z - \left(\frac{A_c}{A_a}\right)_f\right] = \frac{A_c^\circ}{A_a} e^{-\lambda_c t} \qquad (4)$$

where A_x represents the activity of radionuclide x in a sample of sediment, c represents Th-228 and a represents Th-232, $(A_c/A_a)_u$ is the activity ratio of unsupported Th-228 to Th-232, $(A_c/A_a)_z$ is the activity radio at any depth z with an age of t, $(A_c/A_a)_f$ is the lowest activity ratio at depth, (A_c°/A_a) is the activity ratio at the time of deposition and λ_c is the decay constant of Th-228. Activity ratios rather than absolute activities are used in order to correct for minor textural changes such as grain size distribution in the core with depth. $(A_c/A_a)_f$ is expected to be equal to or slightly less than unity. If $t = z/S$ where S is the sedimentation rate, then

$$\ln (A_c/A_a)_u = \ln \left[(A_c/A_a)_z - (A_c/A_a)_f\right]$$

$$= -\frac{\lambda c}{S} z + \ln (A_c^\circ/A_a) \qquad (5)$$

Thus $(A_c/A_a)_u$ or unsupported Th-228 should decrease exponentially with

depth and S may be determined. The idealized distributions of total and unsupported Th-228/Th-232 with age and with depth at several assumed sedimentation rates and initial values of unsupported Th-228/Th-232 are shown in figure 8.

If sediments are not accumulated at a constant rate, the depth profile of Th-228/Th-232 may assume a variety of shapes. Processes such as bioturbation or physical mixing may homogenize the sediments and give uniform Th-228/Th-232 ratio with depth. Changes in sedimentation rate will cause inflexion points in the profile. Horizontal transport of sediments by scouring and slumping may result in layering of the sediments with variable Th-228/Th-232 ratios. Some of the possible shapes of the profiles are shown in figure 9.

Within a small geographical area, if unsupported Th-228 is removed instantaneously from the overlying water, the concentration of Ra-228 in the overlying water does not vary spatially significantly and the water depth of the area does not vary greatly, the inventory of unsupported Th-228 in cores from this area should be quite uniform. Large changes in inventories will indicate horizontal movements of the deposited sediments into or out of that particular location. Moreover, since Th-228 has a half life of 1.9 years, the unsupported Th-228 should become negligible and the Th-228/Th-232 ratio will be indistinguishable from unity after at most 6 half-lives or about 12 years given an analytical uncertainty of ±5% for Th-228 and Th-232. Thus, any sample of sediment with an activity ratio of Th-228 to Th-232 exceeding unity significantly was probably deposited within the last decade.

b. Thorium Isotopic Analyses

With the exception of the core obtained in September at station 15, all

the other twelve cores analyzed contained samples with Th-228/Th-232 ratio significantly above unity suggesting that recent material has been deposited at all the sampling sites in the past decade. At station 15, since only three data points between 1 to 5 cm were available, it is not possible to speculate whether recent material might have been accumulated at other depths.

Initially, speculations based on physical oceanographic data suggested that the seabed in the sampling area may be stable enough to support continuous sedimentation. If this were true, given any sedimentation rate below 2 cm per year, unsupported Th-228 should be confined mostly in the top 5 to 10 cm of the sediments. Thus, only 3 to 5 samples would have to be analyzed for each core in order to define the depth profile. However, none of the cores exhibited a clear trend of an exponential decrease in the Th-228/Th-232 activity ratio with depth (figure 10-17). This implies the absence of a continuous, particle-by-particle deposition at a constant rate. Furthermore, the variations in the activity ratio with depth were so irregular as to preclude any extrapolation between data points and require a much larger number of data points than originally envisioned for defining the depth profiles. The interpretation of the depth profiles is thus limited by the fact that the analytical program does not allow for the determination of Th-228 and Th-232 at every depth of the cores. The inventory of unsupported Th-228 also could not be calculated in most cases.

Few cores even exhibited a clear trend of a monotonic decrease in the activity ratio with depth. Within analytical uncertainties, cores obtained in June at stations 7 and 13 and in September at station 13 came closest to this pattern of distribution. In the remaining cores, older material with

lower activity ratio was often situated on top of younger material so that stepwise variations of the activity ratio with depth were frequently observed. These depth profiles are consistent with episodic sedimentation and horizontal transport of sediments into or out of the study area possibly by storm surges. Bioturbation might have a secondary effect on these depth profiles. Certain organisms can inject more recent sediments at shallower depths to greater depths without homogenizing the entire sediment column. However, in this study, since slices of sediment under a rather large surface area (8 cm x 17.5 cm) were homogenized for the chemical analyses, it seems unlikely that the intensity of bioturbation (as indicated by indices such as the density of worm tubes) was high enough to be the controlling factor of the composition of the sediments. The fact that the activity ratio was not uniform with depth in the entire core indicates that, subsequent to deposition, biological and/or physical mixings of the sediments were not rigorous enough to homogenize more than the top cm or two of the cores.

The depth at which the activity ratio of Th-228/Th-232 dropped to a uniform value close to unity (or the supported level) varied from core to core indicating further that the sedimentation ratio was not uniform in this area. Unsupported Th-228 could be found down to 19 cm at station 7 in June.

The concentration of Th-232 which reflects the composition of the source material of the sediments varied significantly with depth in a number of cores. This further suggests that the source material may have varied with time and it is consistent with an episodic sedimentary history.

At the stations where cores were obtained in both June and September, and analyzed for the thorium isotopes (stations 3, 13, 15 and 20), signifi-

cant differences were observed in the depth profiles of Th-228, Th-232 and Th-228/Th-232 obtained during those two sampling periods. Again, the data may be explained either by spatial inhomogeneity in the composition of the sediments or movements of the sediments in the intervening months.

3. Comparison with Geological Analysis

In terms of the relative stability of the different sites in the study area during a given sampling period, both geological and geochemical data yielded the same conclusion. For example, most of the cores have been classified as stable by geological analysis and recent material (less than 10 years old) was indeed found in these cores. Station 3 was found to be the least stable in both sampling periods while stations 15 and 20 were most stable during June as suggested by geological analysis.

The geochemical analysis, however, has provided independently a much more refined appreciation of the sediment dynamics and thus bed stability in these 'stable' sites. It provides a means for studying the processes that bring sediments to the various sites, the constancy of the source material for the sediments and possible temporal variations in the sediments as a result of processes that operate in the top 10 to 20 cm of the sediments.

D. SUMMARY

The results indicate that:

(1) the seabed in the study area is highly dynamic;

(2) recent material with an age of less than 10 years has been deposited at the disposal site;

(3) sediment did not accumulate at the disposal site at a continuous and constant rate via particle-by-particle deposition;

(4) sedimentation was probably dominated by episodic horizontal movement of sediments;

(5) sedimentation rates at the different locations of the disposal site were not uniform;

(6) the source material for the sediments had varied with time;

(7) among the cores examined, station 3 which situated on a ridge represented the least stable site during both sampling periods; while stations 15 and 20 which situated in the channel were the most stable during June;

(8) between June and September, the depth profiles of the thorium isotopes as well as LOI had changed noticeably suggesting either spatial inhomogeneity of the composition of the sediments or movements of the sediments during intervening months possibly by storms.

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F. FIGURES

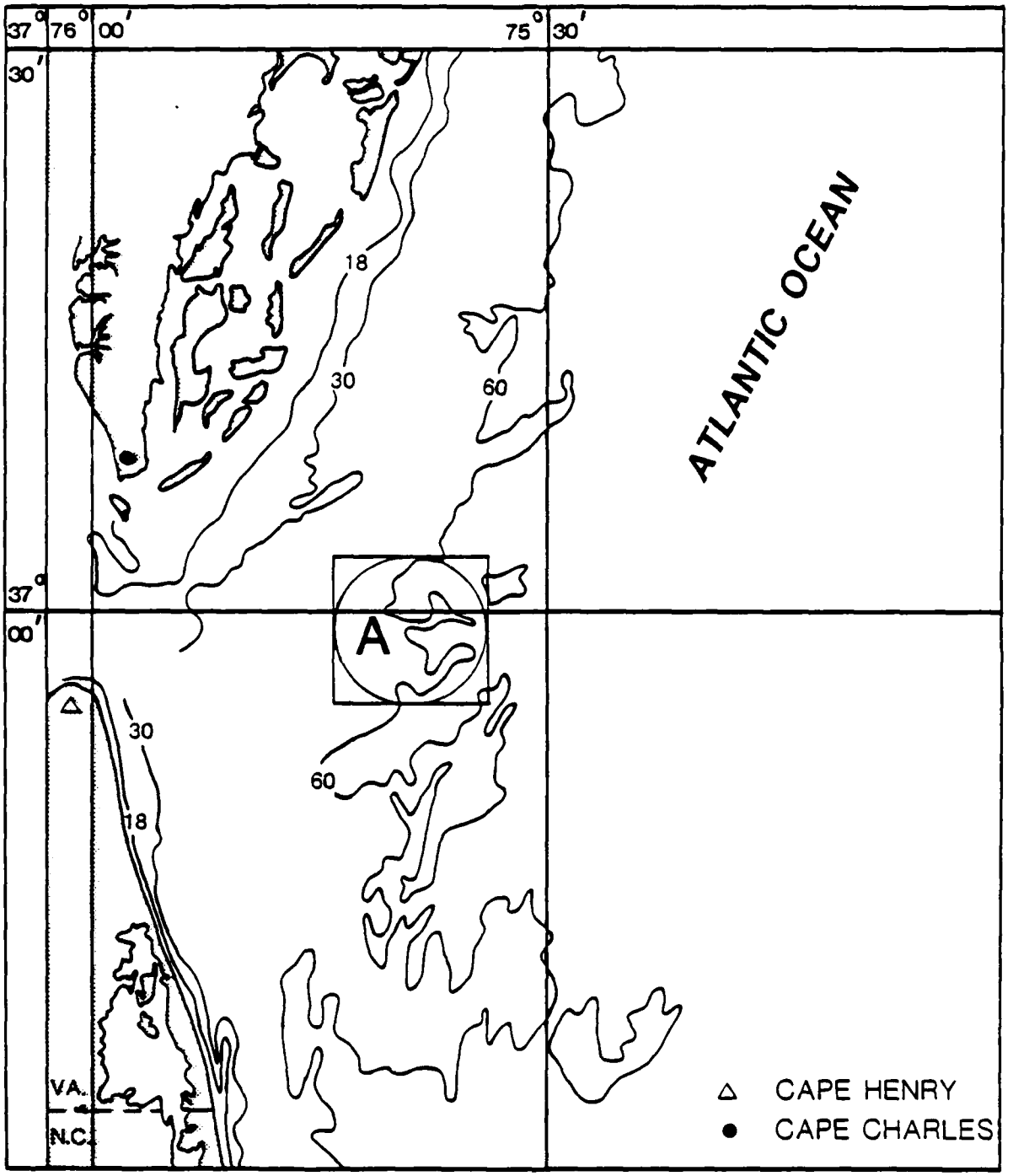

Figure 1. The location map of the Norfolk Ocean Disposal Site (NODS). The disposal site is at the circled area A.

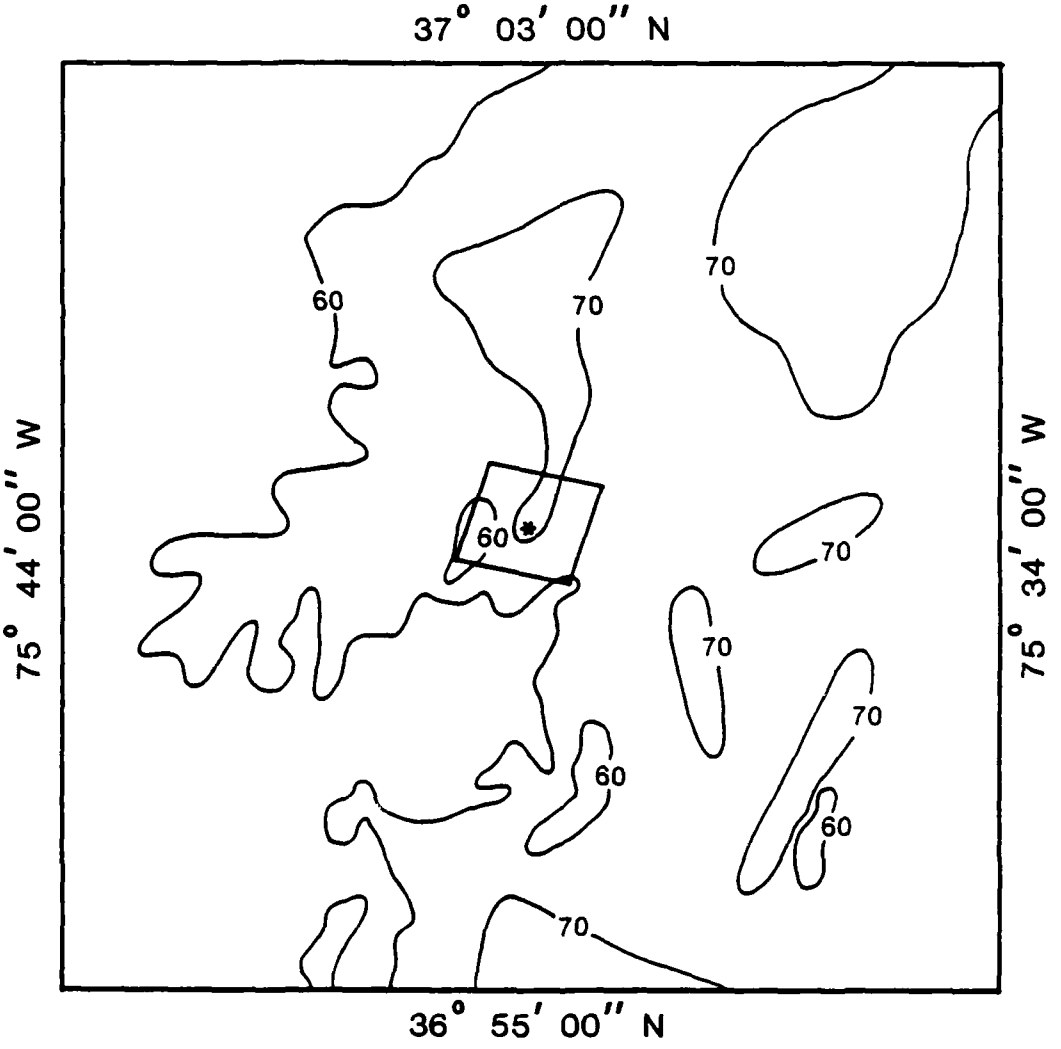

Figure 2. Location map of the study area (approximately 1 square nautical mile) at the center of NODS.

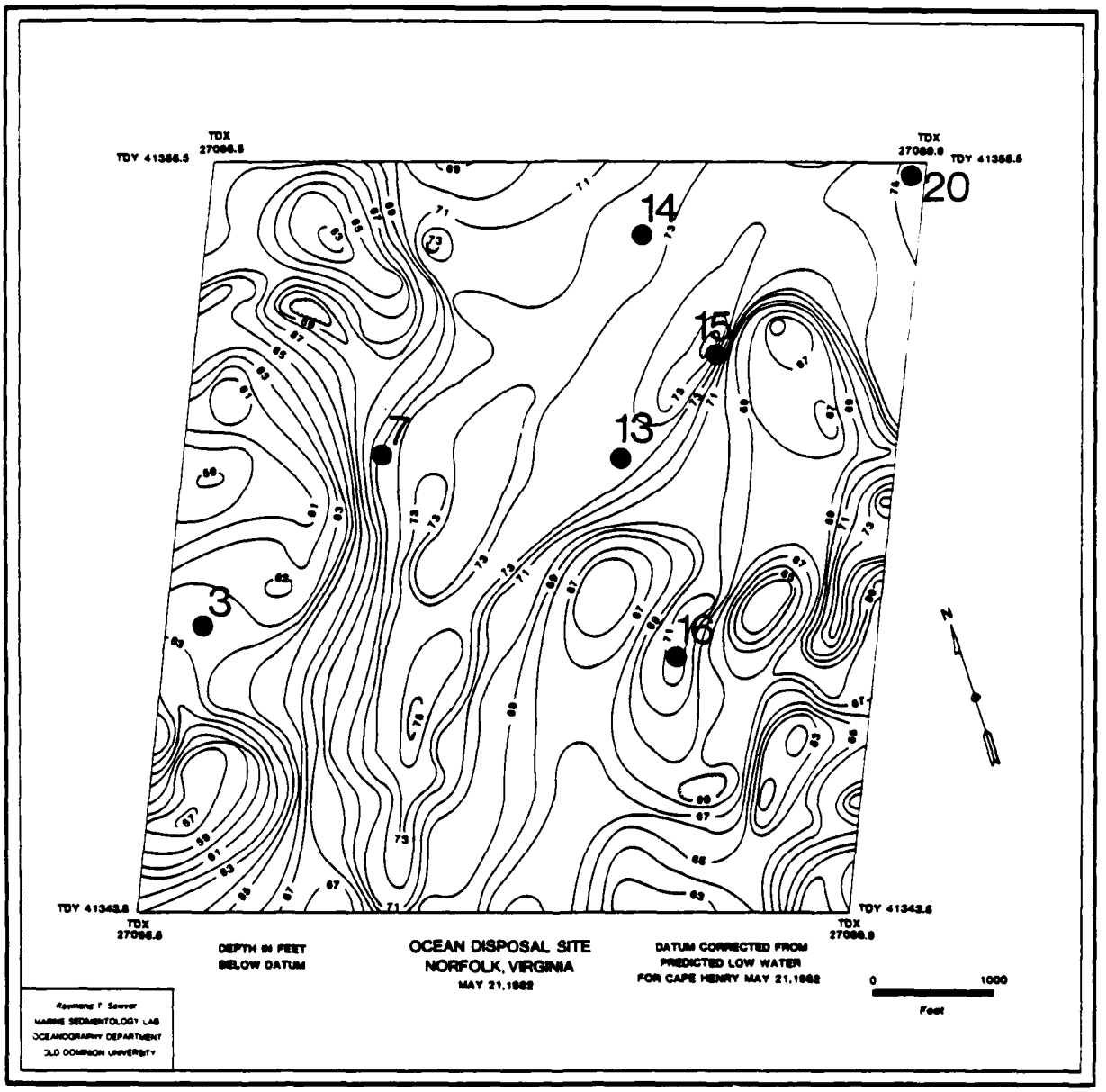

Figure 3. Locations of the cores obtained in June 1982 and the bathymetry of the study area in May 1982.

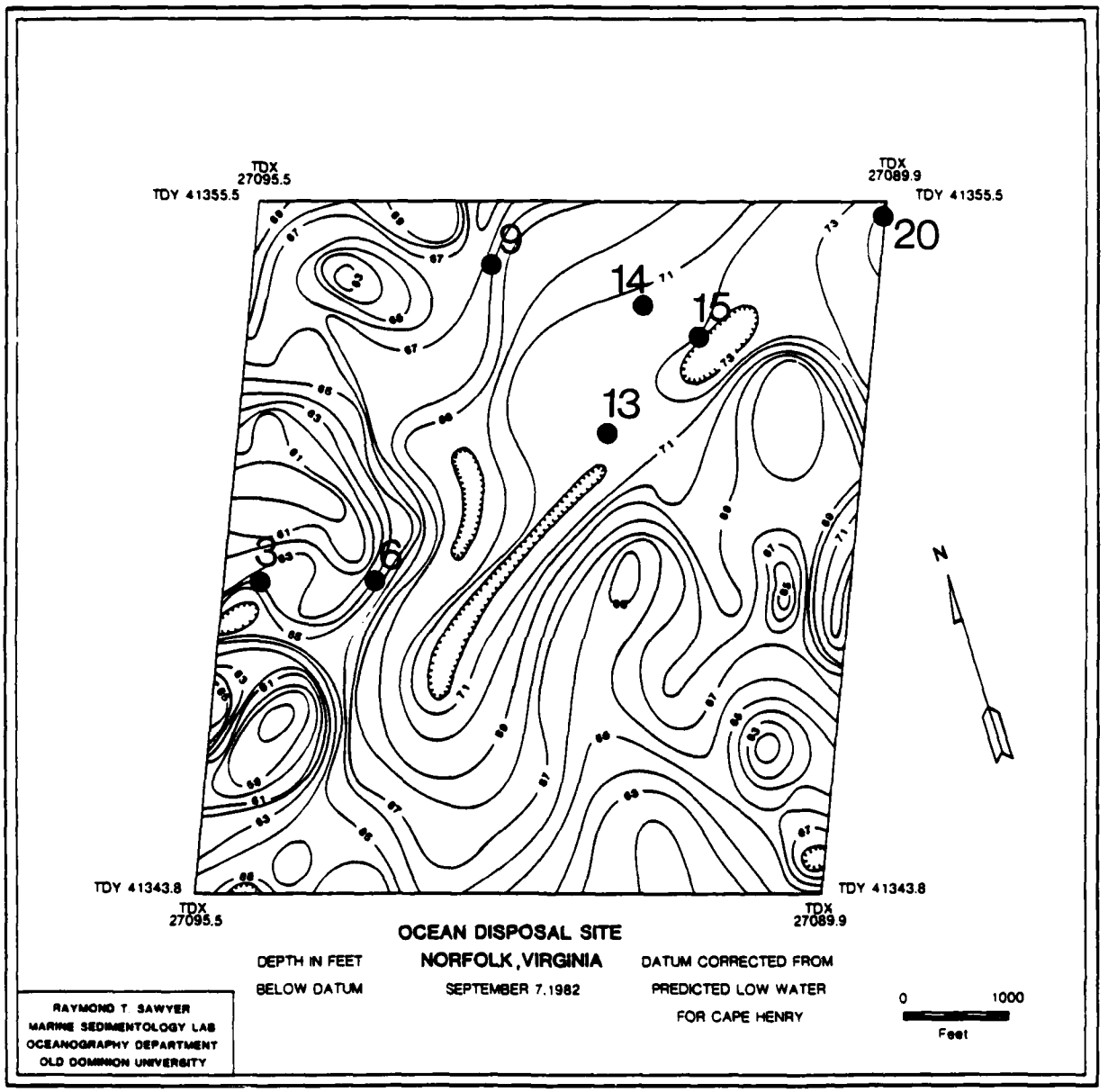

Figure 4. Locations of the cores obtained in September 1982 and the bathymetry of the study area in the same month.

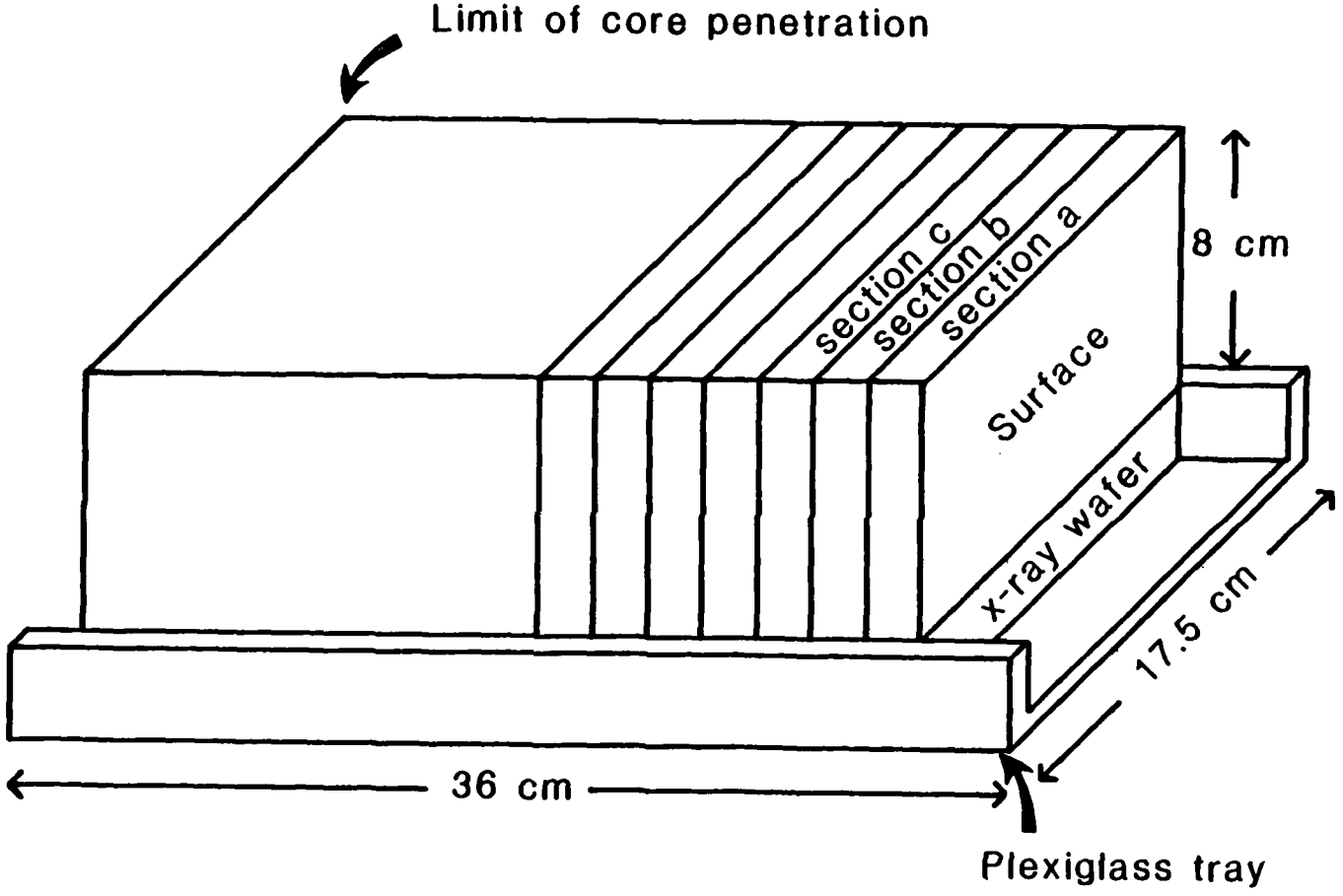

Figure 5. Diagrammatic sketch of box core sample and sub-sample sections for the determination of bulk properties, radiochemical analyses and x-ray radiography.

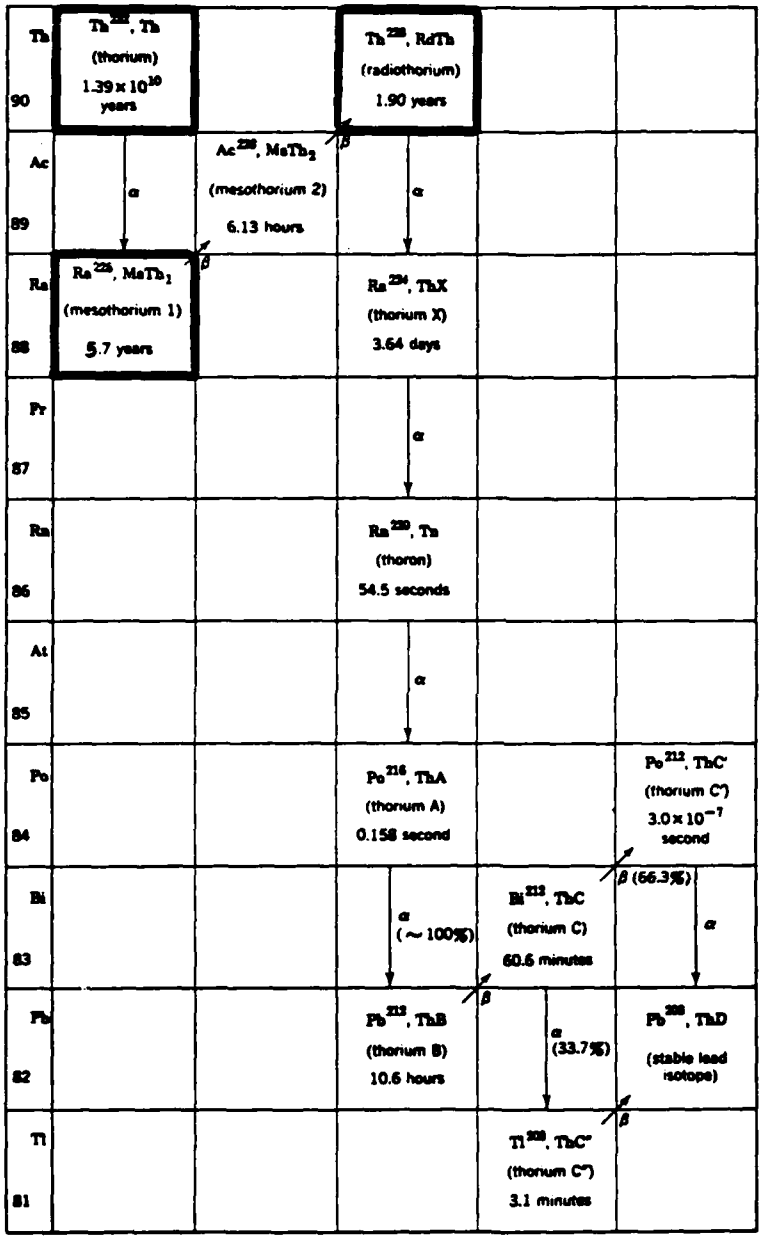

Figure 6. The Th-232 decay series. Radionuclides that are relevant to this study is enclosed in boxes with thickened lines.

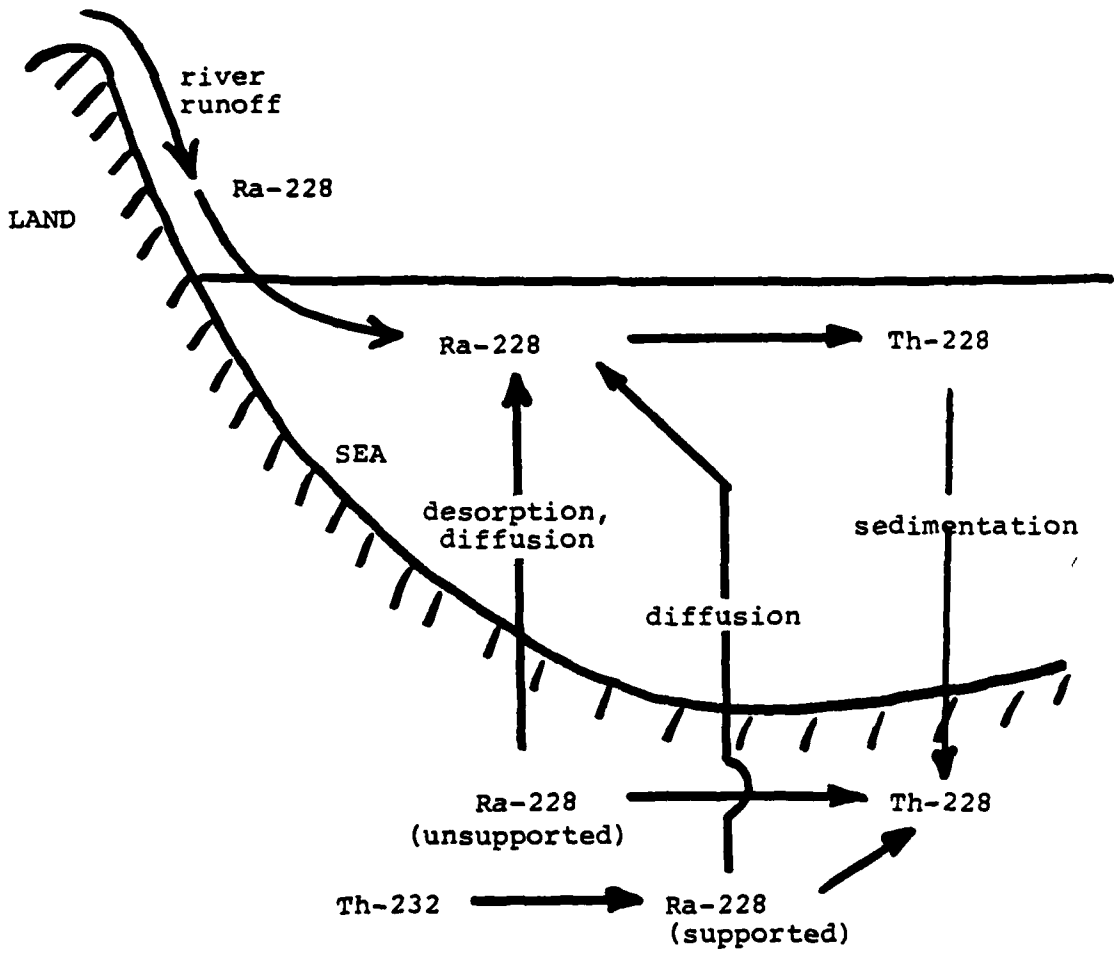

Figure 7. The sources and sinks of Ra-228 and Th-228 in marine sediments.

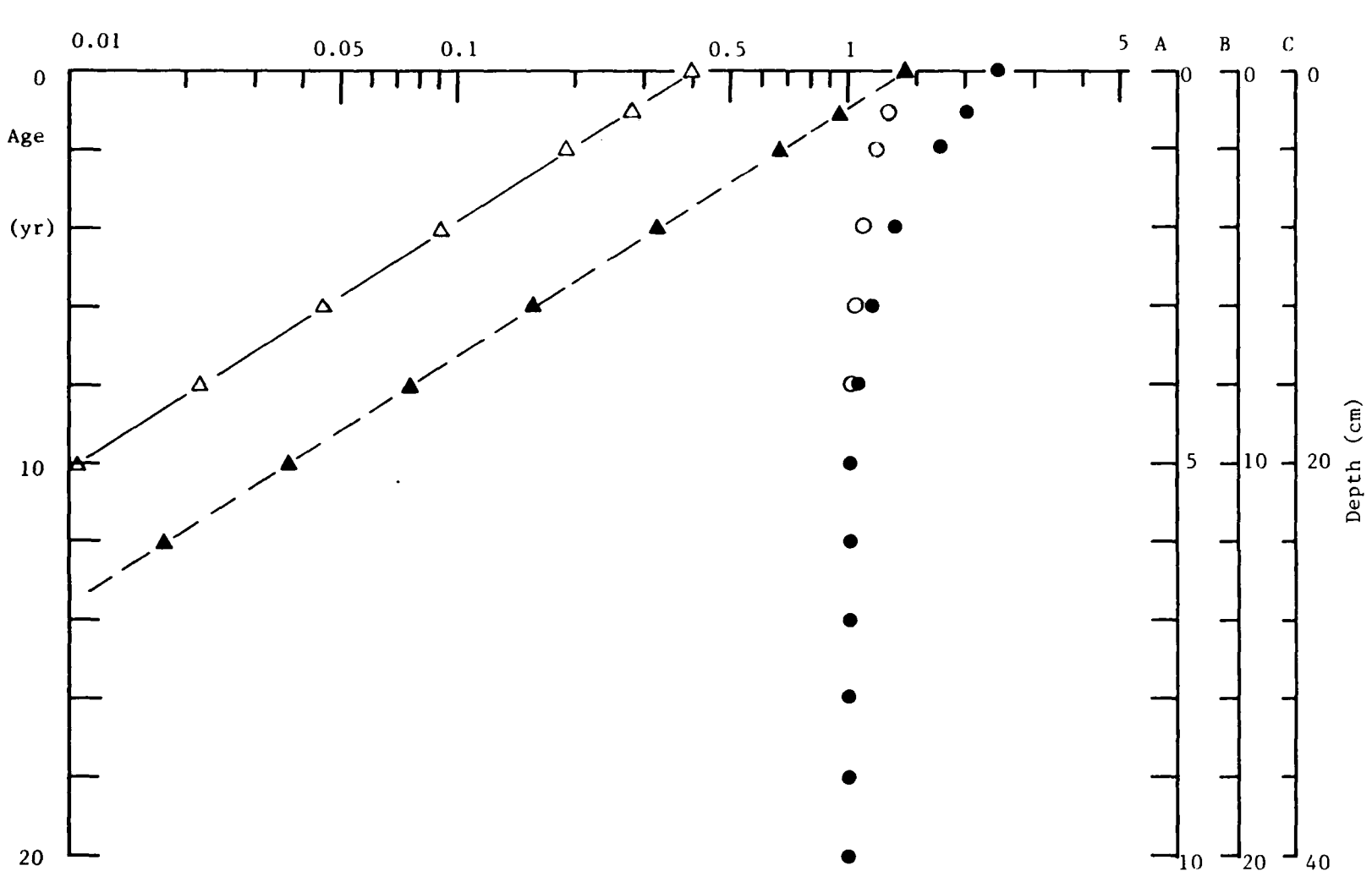

Figure 8. An idealized distribution of total (●, o) and unsupported (▲, Δ) Th-228/Th-232 with age of the sediments and depth in the core with assumed sedimentation rates of 0.5 cm/yr. (scale A), 1 cm/yr. (scale B) and 2 cm/yr. (scale C). For ▲ and ●, an initial unsupported Th-228/Th-232 of 2.4 was assumed. For Δ and o, the initial unsupported Th-228/Th-232 was 1.4.

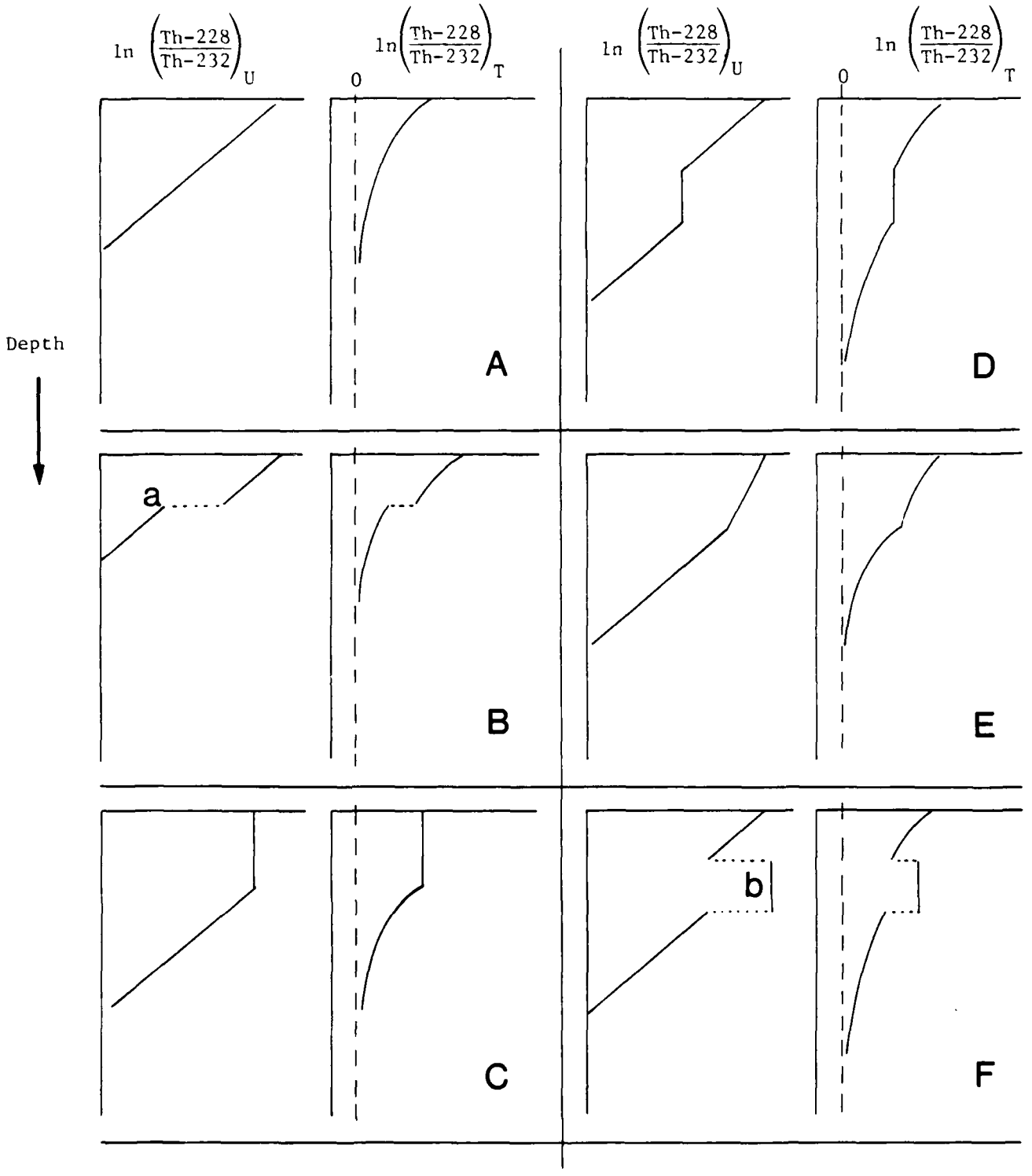

Figure 9. The effects of some sedimentary processes on the idealized depth profile of total Th-228/Th-232 ($(Th\text{-}228/Th\text{-}232)_T$) and unsupported Th-228/Th-232 ($(Th\text{-}228/Th\text{-}232)_U$). A) Particle-by-particle deposition. B) Particle-by-particle deposition disrupted by erosional event (point a). C) Homogenization of surface sediment by physical or biological mixing. D) Particle-by-particle deposition disrupted by slumping. E) Change in sedimentation rate. F) Particle-by-particle deposition disrupted by rapid deposition from a different source of material.

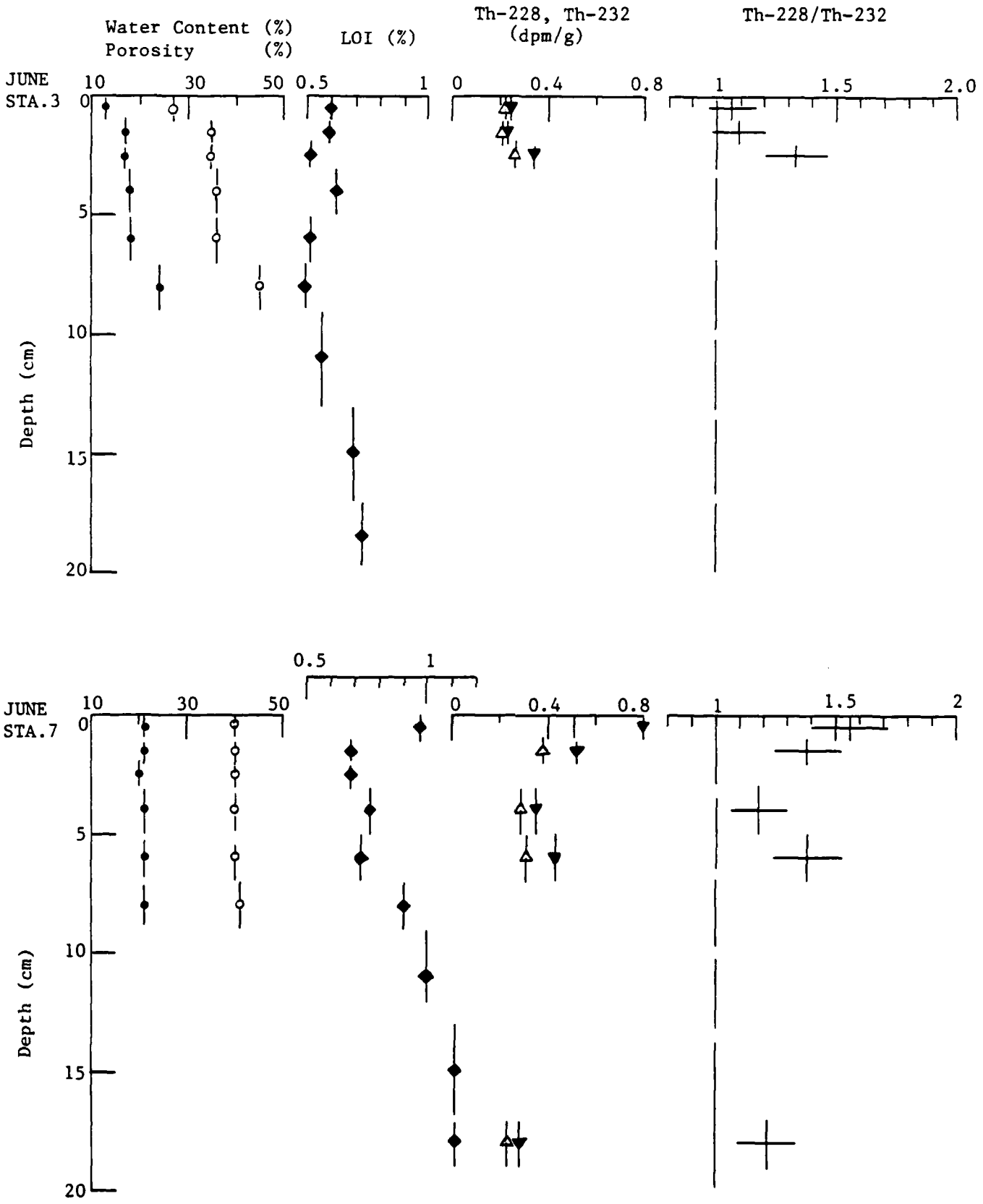

Figure 10. The water content (●), porosity (o), loss on ignition (◆), concentrations of Th-228 (▼) and Th-232 (Δ) and the ratio of Th-228 to Th-232 (+), in cores obtained in June 1982 at stations 3 and 7. The error bars for Th-228/Th-232 are given.

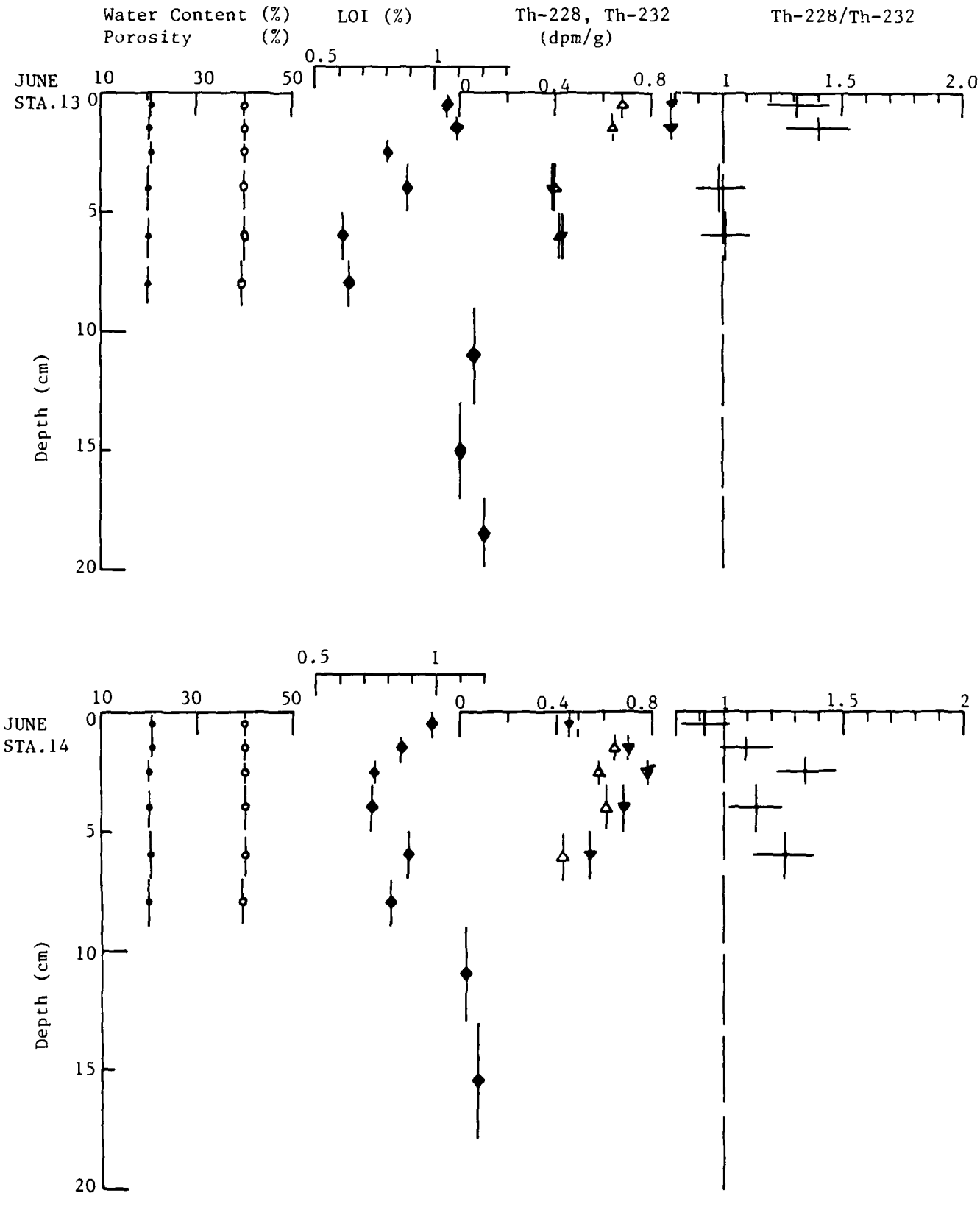

Figure 11. Data for the cores obtained in June 1982 at stations 13 and 14. Symbols are defined as in figure 10.

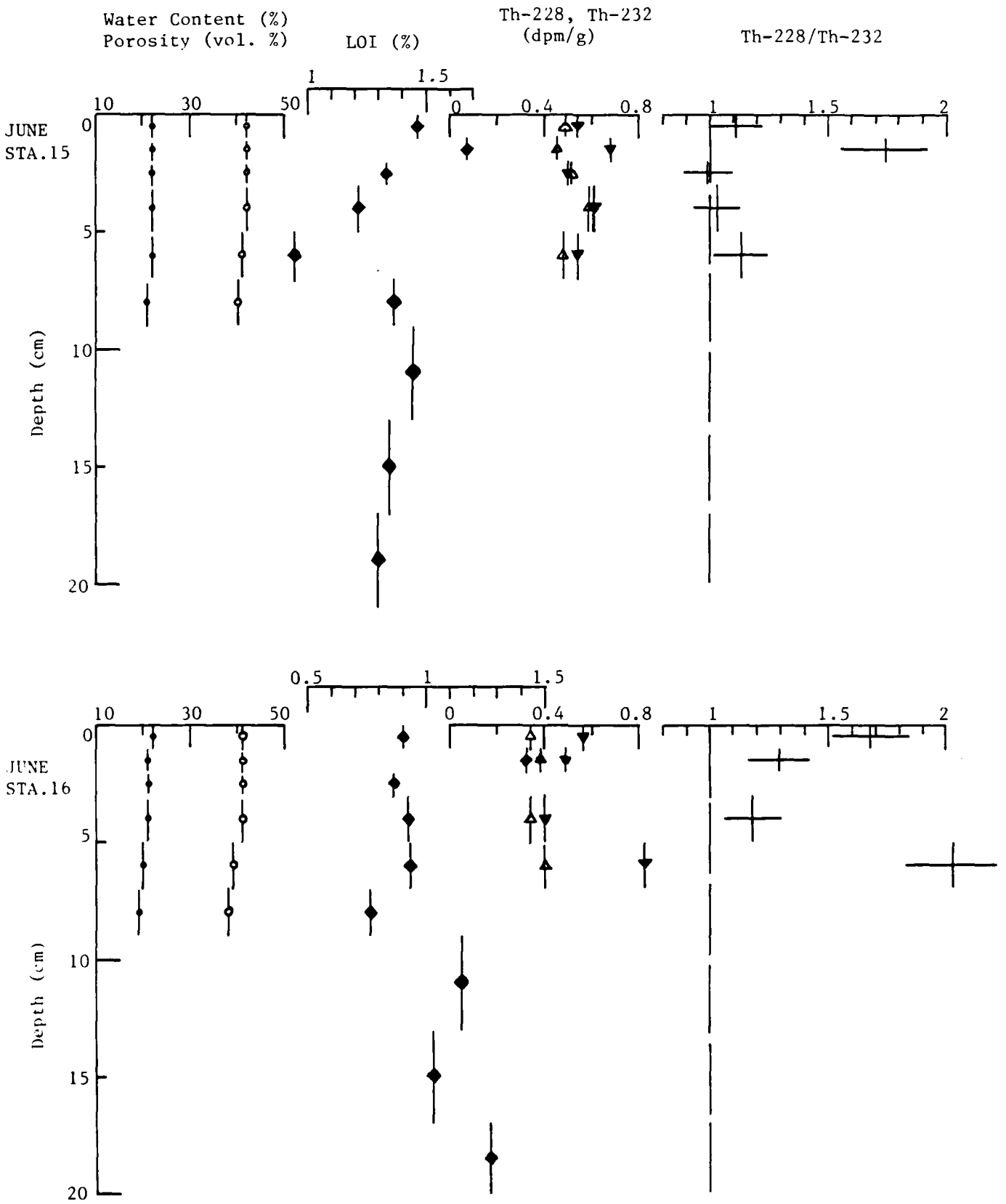

Figure 12. Data for the cores obtained in June 1982 at stations 15 and 16. Symbols are defined as in figure 10.

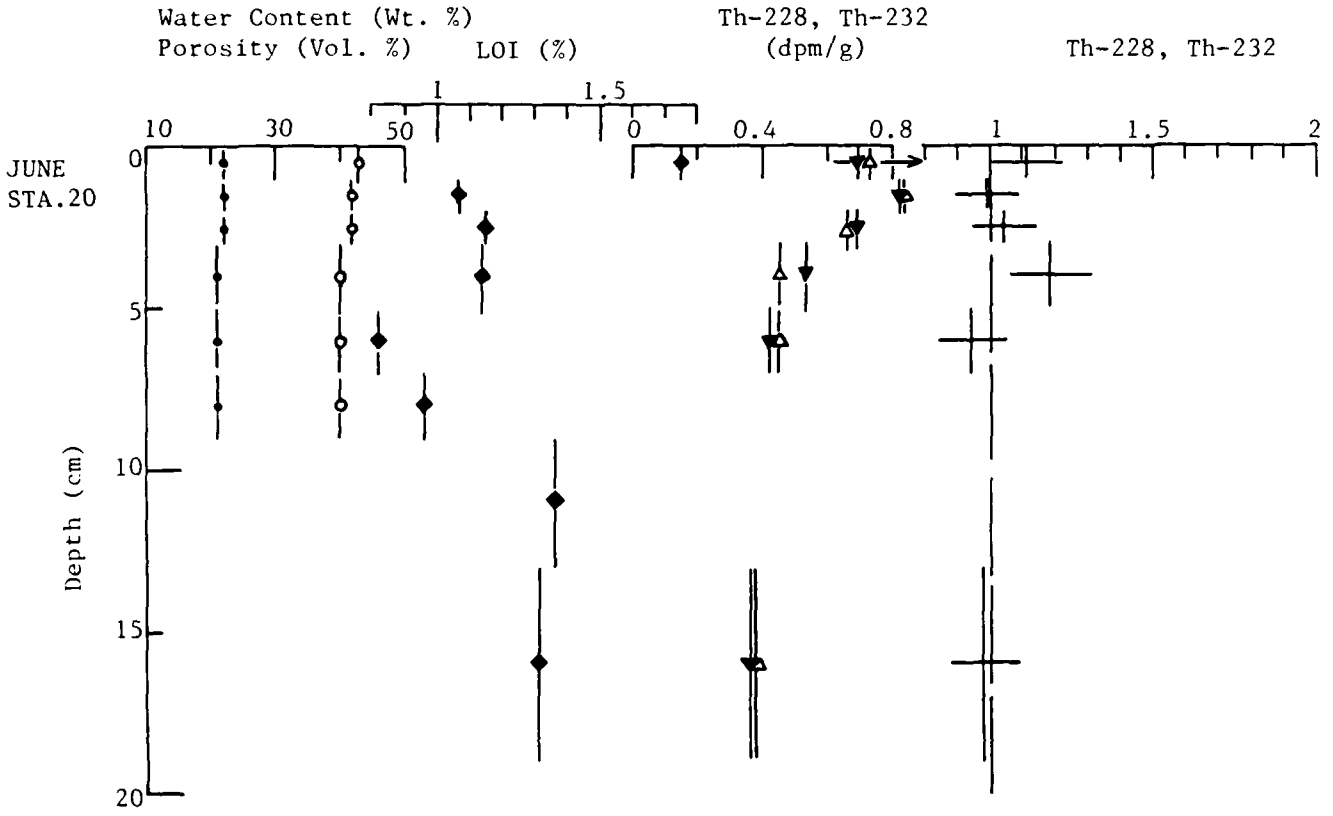

Figure 13. Data for the core obtained in June 1982 at station 20. Symbols are defined as in figure 10.

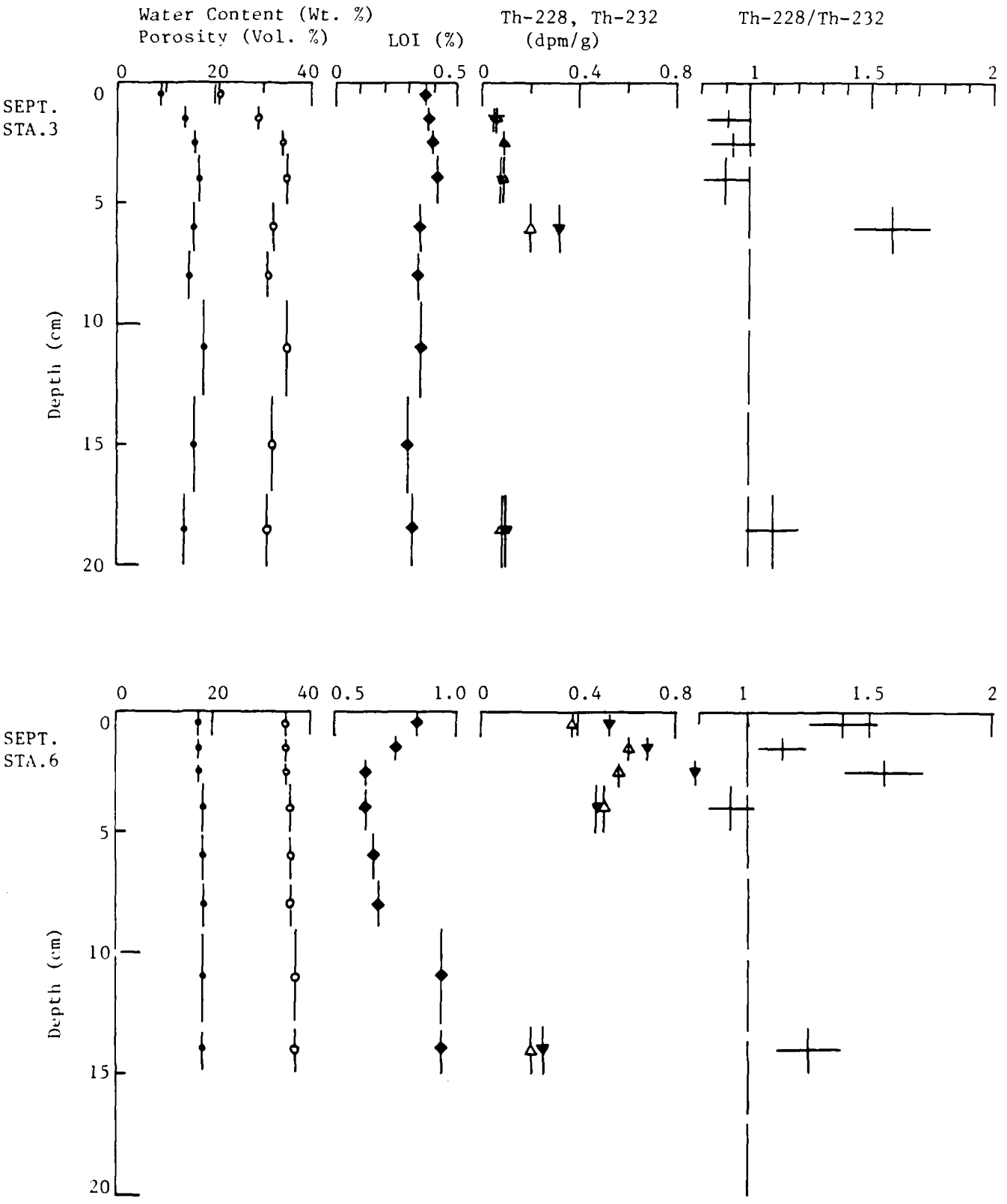

Figure 14. Data for cores obtained in September 1982 at stations 3 and 6. Symbols, are defined as in figure 10.

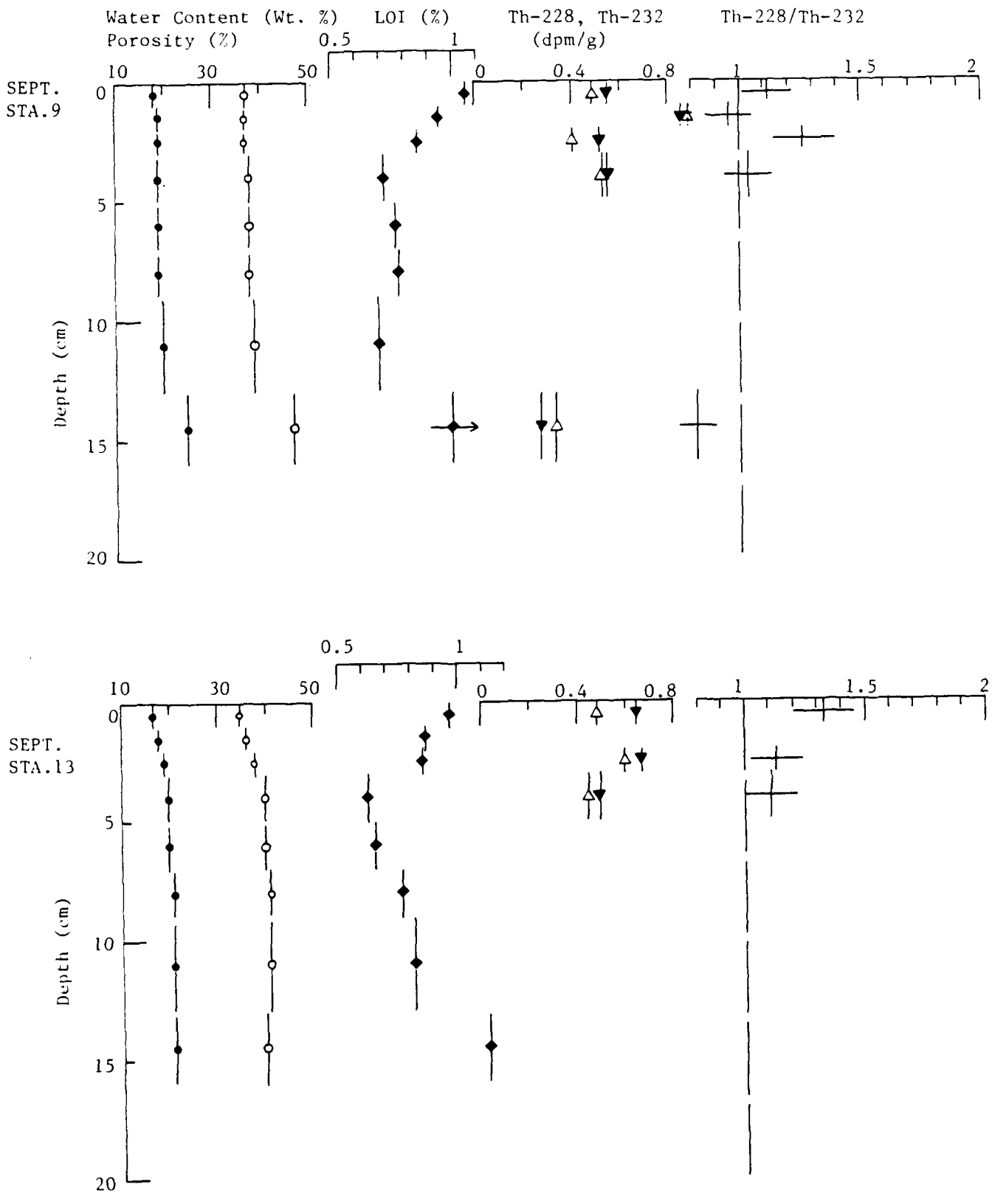

Figure 15. Data for cores obtained in September 1982 at stations 9 and 13. Symbols are defined as in figure 10.

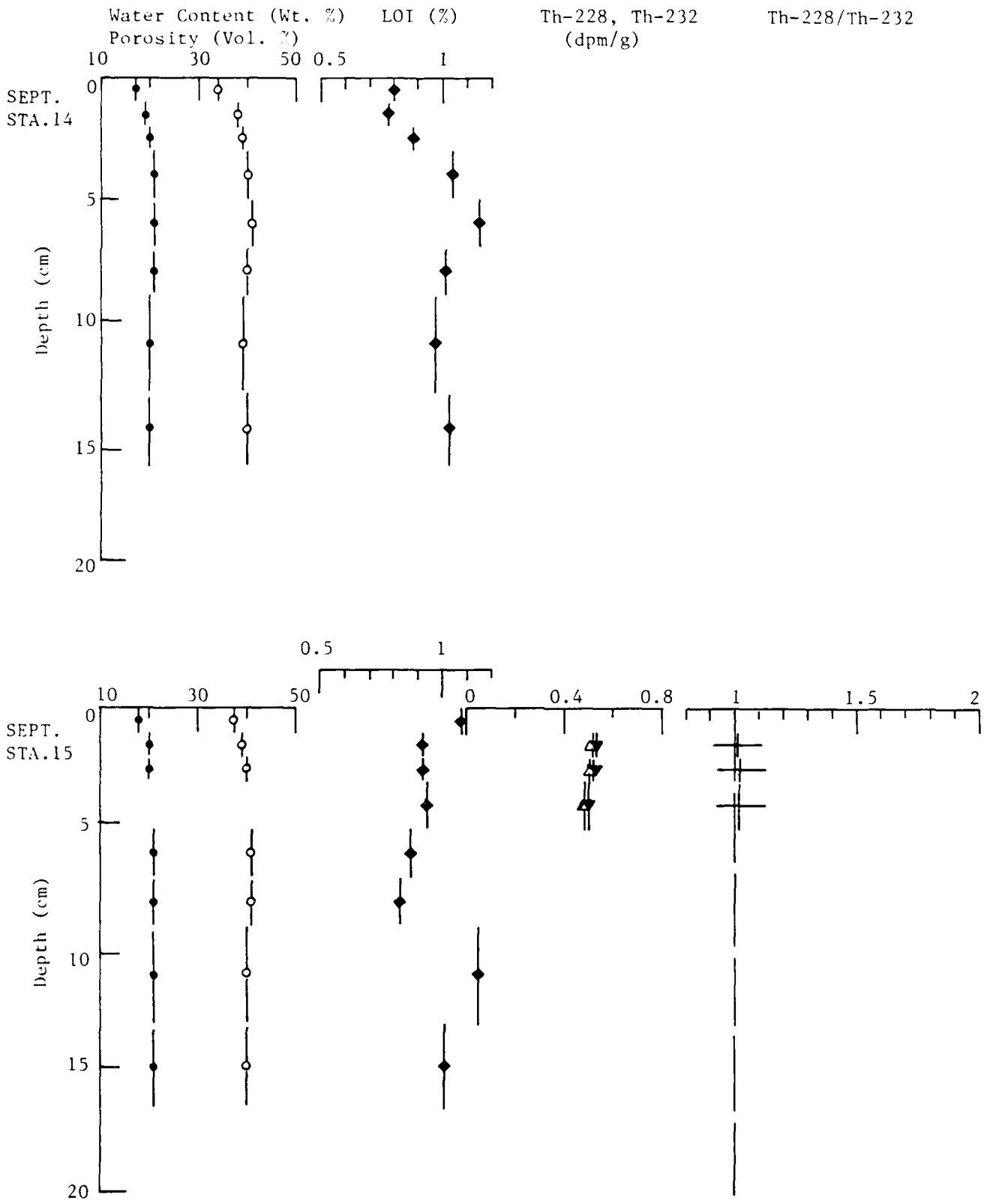

Figure 16. Data for cores obtained in September 1982 at stations 14 and 15. Symbols are defined as in figure 10.

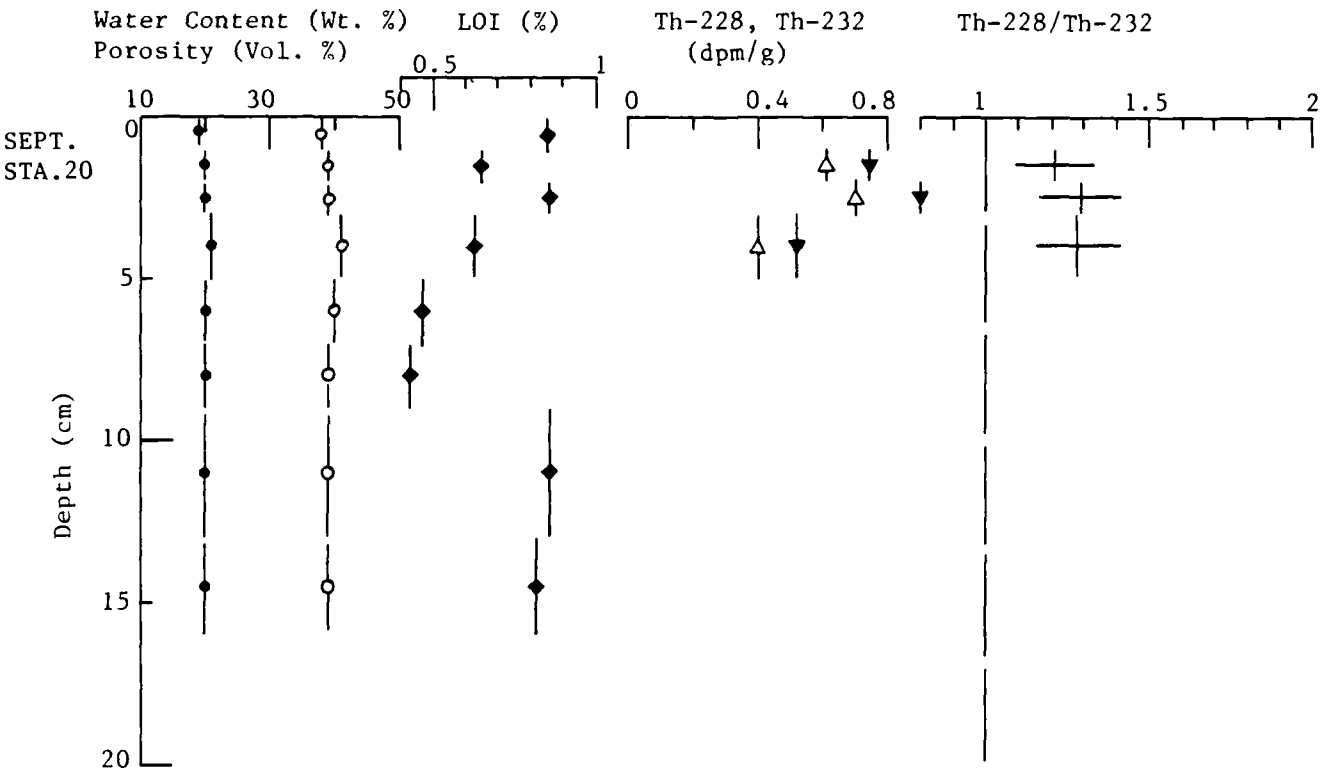

Figure 17. Data for the core obtained in September 1982 at station 20. Symbols are defined as in figure 10.

G. TABLES

Table 1. Station Locations, Water Depths, Overall Bed-Stability According to Geological Analyses and Topographic Locations of Cores Obtained on June 23, 1982 (from Oertel, 1983).

Station No.	Location	Water Depth	Stability	Topographic Location
3	(TD-X) 27095.18 (TD-Y) 41348.39	64 ft.	Moderately Unstable	Ridge
7	27094.00 41351.03	70 ft.	Very Stable	Slope
13	27092.03 41350.93	73 ft.	Very Stable	Channel
14	27092.10 41354.33	72 ft.	Very Stable	Channel
15	27091.46 41352.65	75 ft.	Very Stable	Channel
16	27091.49 41347.76	71 ft.	Stable	Narrow Channel Between Ridges
20	27090.02 41355.34	75 ft.	Very Stable	Channel

Table 2. Station Locations, Water Depths, Overall Bed-Stability According to Geological Analyses and Topographic Locations of Cores Obtained on September 16,1982 (from Oertel, 1983).

Station No.	Location	Water Depth	Stability	Topographic Location
3	(TD-X) 27095.20 (TD-Y) 41348.50	64 ft.	Stable	Ridge
6	27094.12 41348.65	65 ft.	Very Stable	Slope
9	27093.40 41354.70	68 ft.	Very Stable	Slope
13	27092.19 41351.00	72 ft.	Very Stable	Channel
14	27092.10 41354.10	71 ft.	Very Stable	Channel
15	27091.50 41352.60	72 ft.	Very Stable	Channel
20	27089.90 41355.45	74 ft.	Very Stable	Channel

H. APPENDIX

Appendix I: Data

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
June, Station 3. Water Depth: 64 ft. Location: 27095.18; 41348.39.						
0-1	13	27	0.60	0.24	0.22	1.06
1-2	17	35	0.59	0.23	0.21	1.09
2-3	17	35	0.51	0.34	0.26	1.33
3-5	18	36	0.62			
5-7	18	36	0.51			
7-9	24	45	0.49			
9-13			0.56			
13-17			0.69			
17-20			0.73			
June, Station 7. Water Depth: 70 ft. Location: 27094.00; 41351.03.						
0-1	21	40	0.97	0.80	0.51	1.56
1-2	21	40	0.68	0.52	0.38	1.38
2-3	20	40	0.68			
3-5	21	40	0.76	0.35	0.29	1.18
5-7	21	40	0.72	0.43	0.31	1.38
7-9	21	41	0.90			
9-13			0.99			
13-17			1.11			
17-19			1.11	0.28	0.23	1.21

Appendix 1: Data (continued)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
June, Station 13. Water Depth: 73 ft. Location: 27092.03; 41350.93.						
0-1	21	40	1.05	0.89	0.68	1.31
1-2	20	40	1.09	0.89	0.64	1.40
2-3	21	40	0.80			
3-5	20	40	0.88	0.39	0.40	0.99
5-7	20	40	0.61	0.43	0.42	1.01
7-9	20	39	0.64			
9-13			1.16			
13-17			1.10			
17-20			1.20			
June, Station 14. Water Depth: 72 ft. Location: 27092.10; 41354.33.						
0-1	21	40	0.98	0.45	0.49	0.92
1-2	21	40	0.85	0.70	0.64	1.09
2-3	20	40	0.74	0.78	0.58	1.34
3-5	20	40	0.73	0.68	0.61	1.13
5-7	21	40	0.88	0.54	0.43	1.25
7-9	20	39	0.81			
9-13			1.12			
13-18			1.17			

Appendix 1: Data (continued)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
June, Station 15. Water Depth: 75 ft. Location: 27091.46; 41352.65.						
0-1	22	42	1.46	0.54	0.49	1.11
1-2	22	42	1.67	0.78	0.45	1.74
2-3	22	42	1.33	0.50	0.51	0.99
3-5	22	42	1.21	0.61	0.59	1.03
5-7	22	41	0.94	0.54	0.48	1.13
7-9	21	40	1.36			
9-13			1.44			
13-17			1.34			
17-21			1.29			
June, Station 16. Water Depth: 71 ft. Location: 27091.49; 41347.76.						
0-1	22	41	0.90	0.56	0.34	1.68
1-2	21	41	1.42	0.49	0.38	1.29
2-3	21	41	0.86			
3-5	21	41	0.92	0.40	0.34	1.18
5-7	20	39	0.93	0.82	0.40	2.04
7-9	19	38	0.76			
9-13			1.15			
13-17			1.03			
17-20			1.27			

Appendix 1: Data (continued)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
June, Station 20. Water Depth: 75 ft. Location: 27090.02; 41355.34.						
0-1	22	43	1.75	2.41	2.18	1.11
1-2	22	42	1.07	0.82	0.83	0.99
2-3	22	42	1.15	0.69	0.66	1.04
3-5	21	41	1.14	0.53	0.45	1.18
5-7	21	41	0.82	0.42	0.45	0.94
7-9	21	41	0.96			
9-13			1.36			
13-19			1.31	0.36	0.37	0.98
Sept., Station 3. Water Depth: 64 ft. Location: 27095.20; 41348.50.						
0-1	9	21	0.37			
1-2	14	29	0.38	0.05	0.06	0.91
2-3	16	34	0.40	0.09	0.09	0.93
3-5	17	35	0.42	0.08	0.09	0.90
5-7	16	32	0.35	0.32	0.20	1.59
7-9	15	31	0.34			
9-13	18	35	0.35			
13-17	16	32	0.30			
17-19	14	31	0.32	0.10	0.09	1.10

Appendix 1: Data (continued)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
Sept., Station 6. Water Depth: 65 ft. Location: 27094.12; 41348.65.						
0-1	17	35	0.84	0.53	0.38	1.39
1-2	17	35	0.75	0.69	0.61	1.14
2-3	17	35	0.63	0.88	0.57	1.56
3-5	18	36	0.63	0.48	0.51	0.93
5-7	18	36	0.66			
7-9	18	36	0.68			
9-13	18	37	0.94			
13-15	18	37	0.94	0.26	0.21	1.25
Sept., Station 9. Water Depth: 68 ft. Location: 27093.40; 41347.55.						
0-1	18	37	1.06	0.55	0.49	1.12
1-2	19	37	0.95	0.86	0.89	0.96
2-3	19	37	0.86	0.52	0.41	1.27
3-5	19	38	0.72	0.55	0.53	1.04
5-7	19	38	0.77			
7-9	19	38	0.78			
9-13	20	39	0.70			
13-16	25	47	2.38	0.27	0.33	0.82

Appendix 1: Data (continued)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
Sept., Station 13. Water Depth: 72 ft. Location: 27092.19; 41351.00.						
0-1	17	35	0.97	0.65	0.49	1.33
1-2	18	36	0.87			
2-3	19	38	0.86	0.68	0.60	1.13
3-5	20	40	0.63	0.50	0.45	1.11
5-7	20	40	0.66			
7-9	21	41	0.77			
9-13	21	41	0.82			
13-16	21	40	1.13			
Sept., Station 14. Water Depth: 71 ft. Location: 27092.10; 41354.10.						
0-1	17	34	0.80			
1-2	19	38	0.78			
2-3	20	39	0.88			
3-5	21	40	1.04			
5-7	21	41	1.15			
7-9	21	40	1.01			
9-13	20	39	0.97			
13-16	20	40	1.03			

Appendix 1: Data (concluded)

Depth (cm)	Water Content (wt. %)	Porosity (Vol. %)	LOI (wt. %)	Th-228 (dpm/g)	Th-232 (dpm/g)	Th-228 / Th-232
Sept., Station 15. Water Depth: 72 ft. Location: 27091.50; 41352.60.						
0-1	18	37	1.08			
1-2	20	39	0.92	0.53	0.52	1.01
2-3	20	40	0.92	0.52	0.51	1.02
3-5	-	-	0.94	0.50	0.49	1.02
5-7	21	41	0.87			
7-9	21	41	0.83			
9-13	21	40	1.15			
13-16.5	21	40	1.01			
Sept., Station 20. Water Depth: 74 ft. Location: 27089.90; 41355.45.						
0-1	19	38	0.85			
1-2	20	39	0.65	0.74	0.61	1.21
2-3	20	39	0.86	0.90	0.70	1.29
3-5	21	41	0.63			
5-7	20	40	0.47	0.52	0.40	1.28
7-9	20	39	0.43			
9-13	20	39	0.86			
13-16	20	39	0.82			

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